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Stealth Fighter Avionics: 2LM Versus 3LM

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On the first night of Operation DESERT STORM, the public became aware of a unique aircraft that could sneak past enemy radar and bomb targets with pinpoint accuracy. Though the public had vague knowledge of the F-117A, the aircraft's capabilities were largely unknown. Now a recognized political and military tool, the F-117A has been used several times since. The 49th Fighter Wing (FW), located at Holloman AFB New Mexico, has operated the aircraft since 1992 and has spent much of that time converting the aircraft from a special *black world* or very secret operation to a normally-managed tactical aircraft. Much of the effort has been in logistics, specifically repair capability. With the introduction of improved avionics capabilities, the Air Force is in a unique position to determine the best type of logistics support for F-117A avionics. This article discusses the process the wing used to recommend appropriate future repair capabilities. A brief review of the Air Force's conversion from Three Level Maintenance (3LM) to Two Level Maintenance (2LM) will help in understanding the decisions leading to the 2LM philosophy adopted by the Air Force.

Coronet Deuce and the Rand Study

In 1992, the Tactical Air Command (TAC) commissioned the Rand Corporation to conduct a study on the feasibility of implementing an alternative maintenance structure for F-16 avionics. The Rand Study concluded that a new maintenance concept would save resources and still meet all the Air Force's needs.[1] TAC also conducted studies of their own called the Coronet Deuce Exercises. In 1993, TAC declared these exercises a success.[2] Working with the Air Force Material Command (AFMC), they began the Air Force's 2LM program. All TAC units, some Strategic Air Command (SAC) units and eventually all Air Force units began converting to 2LM from 3LM. F-117A avionics maintenance remained an exception and is still largely 3LM today.

The Stealth Fighter Program

The F-117A was originally designed and built deep in the black world and was kept completely secret for about 10 years. In 1981 the Air Force contracted for 29 aircraft.[3] This number was increased to 59 a year later.[4] By Operation DESERT STORM, the F-117A was a proven aircraft, and though its existence was public knowledge, its development and how its systems worked was still cloaked in secrecy.

Since the aircraft was not designed to ever be in the normal *white world*, provisioning decisions were different from those of a normal aircraft program. When the aircraft was initially manufactured, so were a considerable quantity of spare parts, many of which are still in a warehouse at McClellan AFB CA and then soon Palmdale, CA. Between Lockheed Martin and the Air Force, the aircraft was to be completely self-sufficient and if not completely outside the normal Air Force logistics system, at least not easily visible from within. Parts not common to other systems were assigned a non-descriptive (ND) stock number, invisible to non-F-117A users. As the program emerged into the white world, the ND numbers stayed. A few years later, when the EXPRESS[5] system was introduced, those F-117A specific parts were not included in the database. They were kept separate and tracked by the system program office (SPO) in a Lockheed Martin-managed database called Nighthawk.

Though not a unique aircraft in the realm of avionics, many of the components have been modified from other aircraft and are different enough to require modified test equipment. As an example, the aircraft uses the same ultra high frequency (UHF) radio as every other aircraft in the inventory but the power requirements are different, making modification of normal test equipment necessary to test some radio components. These differences made the F-117A program somewhat unique and difficult to support within the established depot system and led to retention of 3LM capability, while the rest of the Air Force was converting to 2LM. For that reason, our completed study of conversion to 3LM is significantly different from the 1992 Rand report and Coronet Deuce exercises.

Another unique aspect of the aircraft is a new management program the F-117A SPO is testing known as the Total System Performance Requirement 800 or simply TSPR 800. Under TSPR 800, most F-117A system management responsibilities are contracted to Lockheed Martin who, in Fiscal Year 1999, will begin performance on a fixed-price contract.[6] One of the management functions is accountability for the repair cycle. In the past, Lockheed Martin has been responsible for repairs that were not possible at base-level; management of assets was the SPO's responsibility. As mentioned earlier, F-117A unique parts are not loaded in EXPRESS and quite possibly never will be. In the future, Lockheed Martin will make a database available to wing customers to provide some visibility of assets in the repair cycle. We believe Lockheed Martin's market focus will help gain control of the repair cycle and drastically reduce cycle time.

Determining What the Program Needs

With all this in mind, the 49th FW Logistics Group Commander directed a study to determine what capability was really needed and what we had that was excess or inefficient. To accomplish these goals we needed to gather data covering the spectrum of

avionics repair, from failure rates to the repair cycle. In examining this data, both from within the wing and from the depot and contractors, we obtained some surprising results. Repair cycle times for assets processed for repairs off base were incredibly long: some process times were over 200 days, so assets were in some stage of the repair cycle, unavailable to the wing, for almost two-thirds of a year.[7] What was even more amazing was that we could not find anyone who knew how to break down that cycle time. Other than what was tracked at base-level through the Intermediate Repair Enhancement Program (IREP),[8] we were unable to quantify how much time the asset was spending in repair versus inbound or outbound queue times.

Cycle time reduction was a major portion of the Coronet Deuce studies accomplished by TAC. What Coronet Deuce did not seem to address in much detail was the effect of 2LM on a wing's ability to deploy and operate in a contingency environment. *AFI 21-130* clearly states that

> To date, we have not identified a simple methodology for capturing the impact of a repair level decision on the in-commission rate for an equipment item or aircraft availability rate for the weapon system.[9]

When determining F-117A needs, it was essential that any change in repair philosophy not adversely affect mission readiness, so a primary concern was the effect of not deploying avionics back-shop repair capability and relying on express shipping would have on wartime sortie rates. Our experience in Kuwait was fairly positive in maintaining readiness without back-shop repair; however, we had to consider two relevant factors. First, our presence in Kuwait has not involved a full squadron sustaining wartime sortie rates. Though utilization rates were higher than at home station, flying still more closely resembled peacetime. Second, after two years of operations in Kuwait we have been able to reduce retrograde (items returning for repair) shipping time to about eight days, though that was only after considerably close management of individual assets. There is no reason to believe we can expect to do as well when the thrust of transportation is on deploying forces.

In order to determine what maintenance capability would be required in the field, we first had to determine what aircraft sortie rates would result during a contingency. We could not find a good model to tell us this in a way that was meaningful so we created our own model. The model is in two parts. The first part determines spares required for support of the 2LM concept and the second for support of a 3LM concept. Some of the factors in the formula were extremely variable and were based on our evaluation of available data. Actual required sortie rates are classified. To keep the study unclassified, we created figures based on experience during Operation DESERT STORM. The two formulas for the model are:

$$(2\text{LM}) * S_r = \frac{\text{TT} + \text{RCT}}{\text{MTBUR/DFH}}$$

$$(3\text{LM}) * S_r = \frac{\text{TT} + \text{RCT}}{\text{MTBF/DFH}}$$

Required Spares (S_r)—The total number of spare line replaceable units (LRUs) required to support a contingency. This represents the total number of spares required in the repair cycle, not just base supply or deployed kits.

Expected Transportation Time (TT)—This is the time to transport the LRU to the repair source and return it to a contingency location. This time is set at 30 days based on our experiences with 49th FW deployments to Kuwait. We found that towards the end of our last deployment, the retrograde transportation time had dropped to about eight days.[10] That time represents over 150 days of very proactive work on the retrograde cycle and does not include time to ship into the theater. As the Air Force works to meets the strategic planning goals, these times should decrease.

Repair Cycle Time (RCT)—This represents the time, in days, an LRU is in the repair cycle to include time at the depot or contractor repair facility. It was produced by the LRU's item manager.

Daily Flying Hours (DFH)—This is the total hours flown over a 24-hour period. Several assumptions were made and were based on previous experience in Southwest Asia. The sortie rate is set at 1.5 sorties per aircraft/per day with an average sortie duration of three hours—81 hours per day for an 18-aircraft deployment. The F-117A performed at these rates during Operation DESERT STORM.

Mean Time Between Unscheduled Repair (MTBUR)—This represents the number of operating hours between LRU removal from an aircraft. If there is no base (deployed) level capability, this is equal to the number of LRUs consumed. MTBUR is calculated by dividing flying hours by LRU total.

Mean Time Between Failure (MTBF)—This represents the number of operating hours between times when an LRU is repaired in the shop and is calculated by dividing flying hours by the bench checked serviceable rate.

Can Not Duplicate Rate (CND)—This represents the number of times LRUs were removed from aircraft and no discrepancy was found in the shop. The CND rate is compared to the repeat rate (bad actor) to determine if CNDs are valid. A high repeat rate (there will always be occasional repeats) would suggest that back-shop procedures were flawed. The wing has historically maintained a repeat rate well below one percent so we considered the CND rate valid. As long as the wing maintains 3LM back-shop capability, the cost for CNDs is in man-hours to pull, test and reinstall the LRU and the cost to run the test equipment. As LRUs transfer to 2LM, CND costs become greater as transportation costs and depot/contractor repair costs must be considered. With ND coded stock numbers and the fixed-price provisions of both the TSPR 800 and a similar contract with Raytheon, those costs become contractor, not Air Force issues. CND rates are included in Table 2 as they are useful in determining the value of maintaining a 2LM screening capability.

Percent Base Repair (PBR)—The number was taken from the Standard Base Supply System (SBSS) database. The number in Table 2 represents a snapshot in time and is quite variable, but it is representative of our capabilities. We confirmed these times with manual records kept by the avionics flight.

The 2LM formula yields the number of LRUs we believe must be available in the total pipeline, under current conditions, to support contingency operations. This includes LRUs in depot or vendor repair, awaiting action, in transit and in kits. Table 1 shows this number in the S_r (2) column.

The 3LM formula indicates the number of LRUs we believe must be available in the total pipeline, under current conditions, to support contingency operations with deployed shop capability.

LRU	TT	RCT	MTBUR	MTBF	DFH	Sr(2)	Sr(3)
Turret	30	5	142	148	81	20	19
Weapons System Computer (WSC)	30	157	770	1680	81	20	9
Projection Display Unit (PDU)	30	182	352	616	81	49	28
Color Multipurpose Display Indicator (CMDI)	30	157	448	474	81	34	32
Flight Control Computer (FLCC)	30	160	493	587	81	31	26
Navigation Interface Autopilot Computer (NIAC)	30	137	513	1232	81	26	11
Flight Control System Panel (FCSP)	30	157	316	725	81	48	21
Display Processor (DP)	30	255	316	493	81	73	47
Expanded Data Transfer Module (EDTM)	30	200	232	385	81	80	48
EDTM Interface Unit (EDTMIU)	30	237	187	316	81	116	68
Data Entry Panel (DEP)	30	200	880	12320	81	21	2
Map Digital Processor (MDP)	30	187	6160	12320	81	3	1
Mass Storage Device Electronics Unit (MSDEU)	30	157	8213	12320	81	2	1
Control Stick	30	157	12320	12320	81	1	1
Throttle Grip, Left	30	157	12320	12320	81	1	1
Throttle Grip, Right	30	157	560	821	81	27	18
Armament Control Panel (ACP)	30	152	2464	12320	81	6	1
Weapons Load Panel (WLP)	30	263	4107	12320	81	6	2
Weapons Interface Panel (WIP)	30	237	12320	12320	81	2	2
Computer Control Panel (CCP)	30	100	12320	12320	81	1	1
Discrete Interface Box (DIB)	30	67	6160	12320	81	1	1
Resistor Interface Box (RIB)	30	*	12320	12320	81	*	*
UHF Radio	30	157	237	246	81	64	62
TACAN RT	30	*	1232	1369	81	*	*
TACAN Adapter	30	*	6160	12320	81	*	*
TACAN Control Panel	30	157	1232	2464	81	12	6
ILS RT	30	*	2464	4107	81	*	*
ILS Control Panel	30	244	4107	6160	81	5	4
IFF RT	30	273	474	684	81	52	36
IFF Control Panel	30	100	4107	4107	81	3	3

* These figures were unavailable from the item managers. Sr(2) and Sr(3) could not be calculated for these items.

Table 1. Required LRUs in the Pipeline—2LM and 3LM

Again, this includes all LRUs in the entire pipeline. Table 1 shows this number in the S_r (3) column.

We used flying hours instead of sorties for these calculations. All failure data for LRUs is calculated using flying hours, as using sorties would mean converting hours to sorties, yielding approximately the same results.

Table 2 provides a fairly definitive view of which LRUs should be converted to the 2LM concept and where we should concentrate our capability for those that remain 3LM.

Current Capability Versus Real Need

To provide a deployable avionics repair capability, large, very heavy containers (vans) were modified to house the necessary test equipment to screen and perform post-repair tests on virtually all the aircraft's avionics components. A full squadron deployment requires 13 pallet positions to move this equipment. In the earlier days of the program this heavy load was considered an acceptable cost for such a unique capability, but today, we cannot assume airlift will be readily available in sufficient time to deploy this capability before readiness spares are consumed. Also, the program has enjoyed several upgrades to the aircraft's avionics suite, including considerable improvement in component MTBF. Finally, with the current push to down size and outsource, we must either find the most efficient means of managing our back-shop capability or we might find ourselves with less capability than is prudent. The Department of Defense has laid out a very comprehensive Logistics Strategic Plan that says we must ensure readiness for war while becoming smaller and more efficient.[11]

An interesting discovery is that the infrared turret, the heart of the F-117A bombing system, is a good candidate for 2LM. This has made us take a serious look at what the numbers really mean as the turret is the number one avionics maintenance driver on the aircraft. Additionally, current turret screening and trouble-shooting capability is quickly fading away as the test equipment is old and replacements are no longer available. The program has spent a considerable sum to develop new repair and screening capability for the turret and associated systems and conversion to 2LM would relegate years of work and millions of dollars to the scrap heap. This is a very difficult decision and is still being discussed at the time of this writing.

Another significant fact is that capability to repair communications and radio navigation systems is very beneficial to the wing. Though some of these components are ND coded, some are in EXPRESS. We can see the EXPRESS items are in short supply Air Force-wide and yet the repair capability that used to exist in every wing before conversion to 2LM is, in many cases, no longer available. Due to the unique configuration of the F-117A systems, we still have that repair capability and are not having the problems seen in some other weapons systems. During our most recent deployment to Southwest Asia we could have repaired 100 percent of the breaks in these systems if the capability had been deployed. Two units tested *could not duplicate* and 10 were repaired in the shop.[12] We do not have a deployable repair capability at this time so we investigated two options. First, the Mobile Electronic Test Set (METS), currently used for the F-15E, performs all the functions of the home station manual test set but faster and with added capability we currently do not have. The added capability is not really needed and the almost $2M price tag discouraged this option.

The second option was to procure additional manual test sets similar to the one we currently have. As many of these test sets were turned-in to the depot during the 2LM conversion, we are procuring them at no cost to the Air Force. We feel this will give us significant capability to repair components without sending them back to home station. We realize shop replaceable units

LRU	Sr(2)	Sr(3)	PBR	CND (%)	AVAILABLE SPARES	2 vs 3
Turret	20	19	99	7	38	2(1)
Weapons System Computer (WSC)	20	9	99	52	3	3
Projection Display Unit (PDU)	49	28	62	9	35	3
Color Multipurpose Display Indicator (CMDI)	34	32	90	2	25	3
Flight Control Computer (FLCC)	31	26	91	8	27	3
Navigation Interface Autopilot Computer (NIAC)	26	11	91	42	23	3
Flight Control System Panel (FCSP)	48	21	85	38	39	3
Display Processor (DP)	73	47	74	10	11	3
Expanded Data Transfer Module (EDTM)	80	48	77	28	34	3
EDTM Interface Unit (EDTMIU)	116	68	69	15	31	3
Data Entry Panel (DEP)	21	2	35	36	25	2+
Map Digital Processor (MDP)	3	1	99	50	21	2+
Mass Storage Device Electronics Unit (MSDEU)	2	1	99	33	26	2+
Control Stick	1	1	99	0	18	2
Throttle Grip, Left	1	1	100	0	14	2
Throttle Grip, Right	27	18	0	9	27	3
Armament Control Panel (ACP)	6	1	25	20	17	2
Weapons Load Panel (WLP)	6	2	42	0	32	2
Weapons Interface Panel (WIP)	2	2	0	0	14	2
Computer Control Panel (CCP)	1	1	90	0	12	2
Discrete Interface Box (DIB)	1	1	0	50	14	2
Resistor Interface Box (RIB)	*	*	0	0	27	2
UHF Radio	64	62	99	2	14	3(2)
TACAN RT	*	*	84	0	904	3(2)
TACAN Adapter	*	*	99	50	436	3(2)
TACAN Control Panel	12	6	99	2	16	3(2)
ILS RT	*	*	99	40	24	3(2)
ILS Control Panel	5	4	66	0	5	3(2)
IFF RT	52	36	88	19	133	3(2)
IFF Control Panel	3	3	99	0	16	3(2)

* These figures were unavailable from the item managers. Sr(2) and Sr(3) could not be calculated for these items.

Table 2. Needs Results (LRUs)—2LM Versus 3LM

(SRUs) must be procured to support this capability, but they are smaller and much easier to ship than the entire LRU. This capability will add no additional size to our deployment package.

Now that we knew what repair capability to retain, we needed to determine how to best configure that capability. The current system, Consolidated Automatic Test Equipment (CATE), gives us all the capability we need, but is much too large for today's deployment scenarios. We're investigating CATE downsizing in order to reduce its deployment footprint to two pallet positions, but have not developed a cost estimate. This, combined with the manual test station, will reduce required pallet positions by 10.

Another possibility is to adapt the Improved Avionics Intermediate Station (IAIS) currently used by F-16 units. It is already compatible with some of our LRUs, though there are software incompatibility problems. The CATE system operates on a C++ based program while IAIS uses the more traditional Abbreviated Test Language for All Systems (ATLAS). We have been unable to find a compiler that would allow C++ and ATLAS to work together, so use of IAIS would require considerable rewrite of code. Additionally, the IAIS would cost about $5M.

Summary

As the F-117A did not develop along the same path as most modern aircraft, there has been room for considerable change in logistics support since the beginning of the program. This unusual development has given us a rare opportunity to create a method to meet the Air Force's logistics goals with unit level planning. The 49th FW's study demonstrated that both savings and increased combat capability can be realized if decisions are based on a combined 2LM/3LM approach to avionics maintenance, as well as a combination of factors including unit readiness rather than strictly cycle time and cost. There are still difficult decisions to be made and we are approaching them in a slow, fact-based manner as we know what we implement now will impact the program for the rest of its service-life.

Notes

1. Abell, J. B. and Shulman, H. L., *Evaluations of Alternative Maintenance Structures*, (Rand Corporation Rep No. R-4205-AF), Santa Monica, CA: Rand Corporation, 1992, 19.
2. Tactical Air Command, *Coronet Deuce III Executive Summary*, Langley AFB VA: 1992, 2.
3. Rich, B. and Janos, L., *Skunk Works*, Boston, MA: Little, Brown and Company, 1994, 89.
4. *Skunk Works*, 91.
5. Execution and Prioritization of Repair Support System (EXPRESS) was developed for various reasons but allows much greater asset visibility in the repair cycle for the limited number of aircraft components currently loaded in the system.
6. Lockheed Martin Skunk Works, *Total System Performance Responsibility, F-117A Weapon System*, Palmdale, CA: 1998, 2.
7. Mason, R., Bear D., et al., *Avionics Capabilities and Future Changes Part 2, 49th Maintenance Squadron*, Holloman AFB NM: 1998, 4.
8. The Air Force's Intermediate Repair Enhancement Program (IREP) is a tool for base-level managers to place emphasis on important logistics and repair issues relating to their assigned weapons system. The program places additional visibility on these critical aspects of repair.
9. Department of the Air Force, *AFI 21-130, Technical Analysis to Determine Criterion for 2 vs 3 Level Repair*, 1998, 4.
10. Hovland, T., *Retrograde Pipeline Summary Report*, Holloman AFB NM: 1998, 3.
11. Department of Defense, *Logistics Strategic Plan*, Washington, DC: 1998, 6.
12. *Retrograde Pipeline Summary Report*, 6.

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